MASTER

Modeling and control of a mobile electro-hydraulic positioning system

van den Bosch, Lex P.Y.

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Modeling and control of a mobile electro-hydraulic positioning system

Master's Thesis

Lex P.Y. van den Bosch
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Supervisors:
dr.ir. Emanuel Feru (TRIDEC BV, Son)
dr.ir. Igo J.M. Besselink (TU/e, Eindhoven)

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Abstract

This thesis describes the development and evaluation of a control strategy for a mobile electro-hydraulic positioning system, named Electronic Kingpin Steering System (EKSS). It steers axles on a semi-trailer to obtain reduced tire wear, improved fuel efficiency, lower emissions, and enhanced maneuverability. The contributions include the identification of trailer steering requirements, the development of a simulation model, and the introduction of a novel control strategy for the EKSS system, named Advanced Valve and Pump Control (AVaPCo).

A model of the new EKSS is made using MATLAB Simulink Simscape, which allows evaluating component sizing and control principles. Components are parameterized based on available measurement data or datasheets. Additionally, a multibody model in the form of a steerable semi-trailer axle is introduced, coupling the steering hydraulics model to a multibody model, including the tire model.

The analysis of the existing design reveals inefficiencies in decoupled pump and steering valve control. The AVaPCo architecture couples pump and position control, where it dynamically controls pump pressure to lower energy usage, and incorporates a feedforward (FF) component for enhanced tracking performance. Additionally, the new design suggests lowering the accumulator's pre-charge pressure to enhance energy efficiency.

The use of a novel Smart Linear Actuator (SLA) to control the directional steering valve position eliminates valve hysteresis. Combining its position feedback with fluid flow estimation enables hydraulic load estimation for use in the pump control. Conventional linear control theory is applied to both valve and pump control to ensure the limited computing power of the ECU is not a constraint. The use of input linearization and enabled controllers ensures that linear control theory remains effective.

A performance evaluation comparing AVaPCo to the current control system demonstrated reduced energy consumption and superior tracking results across various operating points. Improvements vary depending on workload and system configuration. In low load and medium load operation, the improvement in tracking performance varies between 11% and 72%, while power consumption decreased by 18% to 66%. High load operation, however, results in an increase in energy consumption of up to 11%, but tracking performance in this region also increases up to 80%.

Recommendations for further refinement and validation include rigorous testing of the load estimator, practical testing of the entire AVaPCo system, effective component sizing, and additional measurements with a test semi-trailer to enhance the tire model. These steps aim to refine the control strategy and deepen the understanding of the forces involved in steering, ultimately advancing the EKSS.